(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 February 2003 (20.02.2003)

PCT

(10) International Publication Number
WO 03/015459 A3

(51) International Patent Classification[7]: H04R 3/00

(21) International Application Number: PCT/EP02/09030

(22) International Filing Date: 12 August 2002 (12.08.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/928,229 10 August 2001 (10.08.2001) US

(71) Applicant: RASMUSSEN DIGITAL APS [DK/DK]; Johannevej 26, DK-2920 Charlottenlund (DK).

(72) Inventor: RASMUSSEN, Erik, W.; Johannevej 26, DK-2920 Charlottenlund (DK).

(74) Agents: LEEMING, John, Gerard et al.; J.A. KEMP & CO., 14 South Square, Gray's Inn, London WC1R 5JJ (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

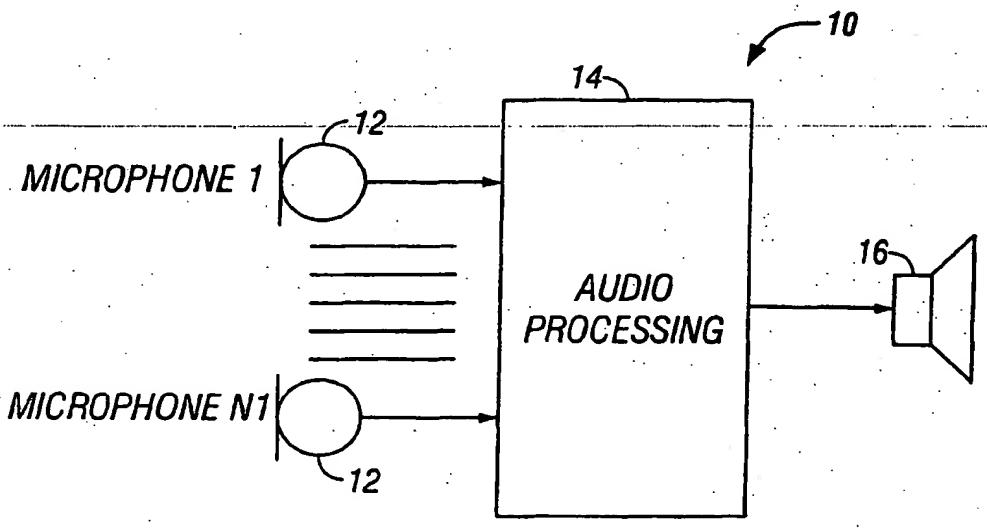
(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
20 November 2003

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SOUND PROCESSING SYSTEM THAT EXHIBITS ARBITRARY GRADIENT RESPONSE



(57) Abstract: A sound processing system including at least one microphone, an audio processor, and at least one output device. The audio processor includes an analog beamformer, a microphone equalizer, and an apparent incidence processor. Two different embodiments of the apparant incidence processor are disclosed, that is, a wave generation method and a forward filtering method. Both embodiments use the same principles to estimate the properties of the individual waves of the sound field. With the present invention, it is possible to implement arbitrary directivity responses using a small number of microphones only, that is, two or three microphones. The present invention offers improved noise reduction also for environments with many independent noise sources. Furthermore, the present invention works for signals and noises with arbitrary statistics.

WO 03/015459 A3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/09030

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04R3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 195 40 795 A (DEUTSCHE TELEKOM AG) 7 May 1997 (1997-05-07) column 1, line 3 - line 17 column 2, line 34 -column 6, line 14; figures 1-5	1,23
Y		2-6, 15-19, 21, 24-28, 34-38,40
Y	EP 0 942 628 A (SIEMENS HEARING INSTR INC) 15 September 1999 (1999-09-15) the whole document	2-6, 24-28

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 September 2003	22.09.03

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Nieuwenhuis, P

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/09030

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 99 45741 A (MCATEER JEFFREY PHILLIP ;MWM ACOUSTICS LLC (US); MICHEL ALAN DEAN) 10 September 1999 (1999-09-10) page 7, line 20 -page 8, line 28; figure 1	2-6, 24-28
A	US 6 160 757 A (TAEGER WOLFGANG ET AL) 12 December 2000 (2000-12-12) column 8, line 15 - line 39 column 11, line 12 - line 51; figures 1,8	1,23
X	EP 0 795 851 A (TOKYO SHIBAURA ELECTRIC CO) 17 September 1997 (1997-09-17) page 4, line 58 -page 7, line 59 page 9, line 10 -page 11, line 22; figures 3-5B,11-13	1,12,20, 23,31,39
Y		15-19, 21, 34-38,40
X	EP 1 065 909 A (GOLDIN ALEXANDER) 3 January 2001 (2001-01-03) paragraph '0060! - paragraph '0078!; figures 4-8	1,12,20, 23,31,39
Y		15-19, 21, 34-38,40
Y	KELLERMANN W: "A SELF-STEERING DIGITAL MICROPHONE ARRAY" SPECTRAL ESTIMATION AUDIO AND ELECTROACOUSTICS. TORONTO, APRIL, 14 - 17, 1991, INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH & SIGNAL PROCESSING. ICASSP, NEW YORK, IEEE, US, vol. 5 CONF. 16, 14 May 1991 (1991-05-14), pages 3581-3584, XP000242750 ISBN: 0-7803-0003-3 page 3582, left-hand column, last paragraph -page 3584, left-hand column, paragraph 4	15-18, 34-37
Y	EP 1 091 615 A (RIBIC ZLATAN) 11 April 2001 (2001-04-11) paragraph '0006! - paragraph '0007!	19,38
Y	EP 0 883 325 A (UNIV MELBOURNE) 9 December 1998 (1998-12-09) column 6, line 21 -column 7, line 18 column 10, line 42 -column 11, line 11; figure 1	21,40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP 02/09030

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

1-6,12-21,23-28,31-40

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-6, 23-28

Independent claim 1 relates to an audio processor for a sound processing system comprising a plurality of microphones and an output device, wherein the system amplifies waves originating from sources in close proximity to the plurality of microphones, the audio processor comprising:

- a near field gain controller (204) having an input connected to the plurality of microphones, wherein a gain is derived in frequency bands such that a high gain is assigned to frequency bands containing a significant portion of near field waves and a low gain is assigned to frequency bands containing a significant portion of far field waves; and
- a signal filter for filtering the input signals according to the frequency dependent gain.

Independent claim 23 relates to a method of audio signal processing corresponding to claim 1, respectively.

1.1. Claims: 2-6, 24-28

Apparatus claim 2, which depends on independent claim 1, further specifies that the audio processor comprises:

- a microphone equalizer (200) having an input connected to the plurality of microphones and input connected to the near field controller, wherein at least one of the signals from the plurality in filtered with an equalization filter.

Claim 24, which depends on independent claim 23, relates to a method of audio signal processing corresponding to claim 2.

1.2. Claim : 9

Apparatus claim 15, which depends on independent claim 1, further specifies that the output of the near field controller (204) is in the frequency domain.

2. Claims: 7, 29

Apparatus claim 7, which depends on independent claim 1, further specifies that the processor comprises a gain smoother (96) to prevent the occurrence of abrupt gain changes.

Claim 29, which depends on independent claim 23, relates to a method of audio signal processing corresponding to claim 7.

3. Claim : 8

Apparatus claim 8, which depends on independent claim 1, further specifies that the processor comprises a gain mapper (164) for reducing time domain aliasing.

4. Claims: 10, 11, 30

Apparatus claim 10, which depends on independent claim 1, further specifies that the audio processor comprises:
- a beamformer (202) having an input connected to the plurality of microphones and an output connected to the input of the near field gain controller (204), wherein the input signals are preprocessed before being passed to the near field gain controller.

Claim 30, which depends on independent claim 23, relates to a method of audio signal processing corresponding to claim 10.

5. Claims: 12-21, 31-40

Apparatus claim 12, which depends on independent claim 1, further specifies that the near field gain controller (204) comprises:
- a power filter (220) for measuring the signal power with a predefined time constant; and
- a near field gain function applier (226) for deriving the raw channel gains.

Claim 31, which depends on independent claim 23, relates to a method of audio signal processing corresponding to claim 12.

6. Claims: 22, 41

Apparatus claim 22, which depends on independent claim 1, further specifies that the audio processor comprises:
- an analog beamformer (18) having an input connected to the plurality of microphones, and
- at least 2 A/D converters (24) having different resolutions and being connected to the output of the analog beamformer (18) and to the input of the apparent incidence processor.

Claim 41, which depends on independent claim 23, relates to a method of audio signal processing corresponding to claim 22.

Please note that all inventions mentioned under item 1, although not

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 02/09030

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
DE 19540795	A	07-05-1997	DE 19540795	A1	07-05-1997
EP 0942628	A	15-09-1999	EP 0942628	A2	15-09-1999
WO 9945741	A	10-09-1999	AU 2797599	A	20-09-1999
			WO 9945741	A2	10-09-1999
US 6160757	A	12-12-2000	FR 2768290	A1	12-03-1999
			EP 0903960	A1	24-03-1999
			JP 11146494	A	28-05-1999
EP 0795851	A	17-09-1997	JP 9251299	A	22-09-1997
			DE 69713647	D1	08-08-2002
			DE 69713647	T2	05-12-2002
			EP 0795851	A2	17-09-1997
			US 6009396	A	28-12-1999
EP 1065909	A	03-01-2001	EP 1065909	A2	03-01-2001
			JP 2001045592	A	16-02-2001
EP 1091615	A	11-04-2001	EP 1091615	A1	11-04-2001
			AT 230917	T	15-01-2003
			AU 7289300	A	10-05-2001
			CA 2386584	A1	12-04-2001
			DE 69904822	D1	13-02-2003
			WO 0126415	A1	12-04-2001
			JP 2003511878	T	25-03-2003
EP 0883325	A	09-12-1998	EP 0883325	A2	09-12-1998
			US 6603858	B1	05-08-2003